



NuMI target

NuMI Target
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FNAL beam test

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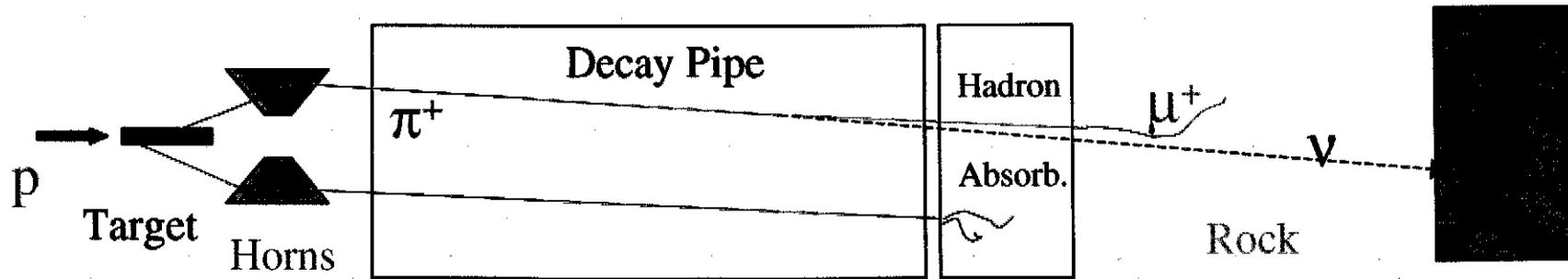
Target construction done at IHEP



Neutrino Beam Production

120 GeV protons hit target

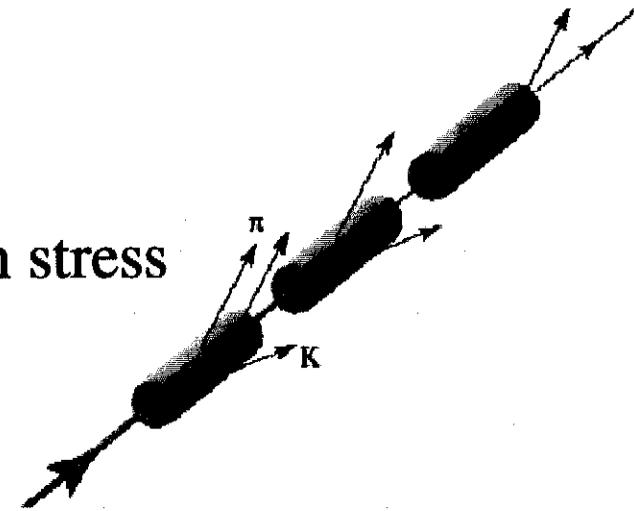
produce π^+ which decay to $\mu^+ \nu$



Narrow target lets π escape out sides

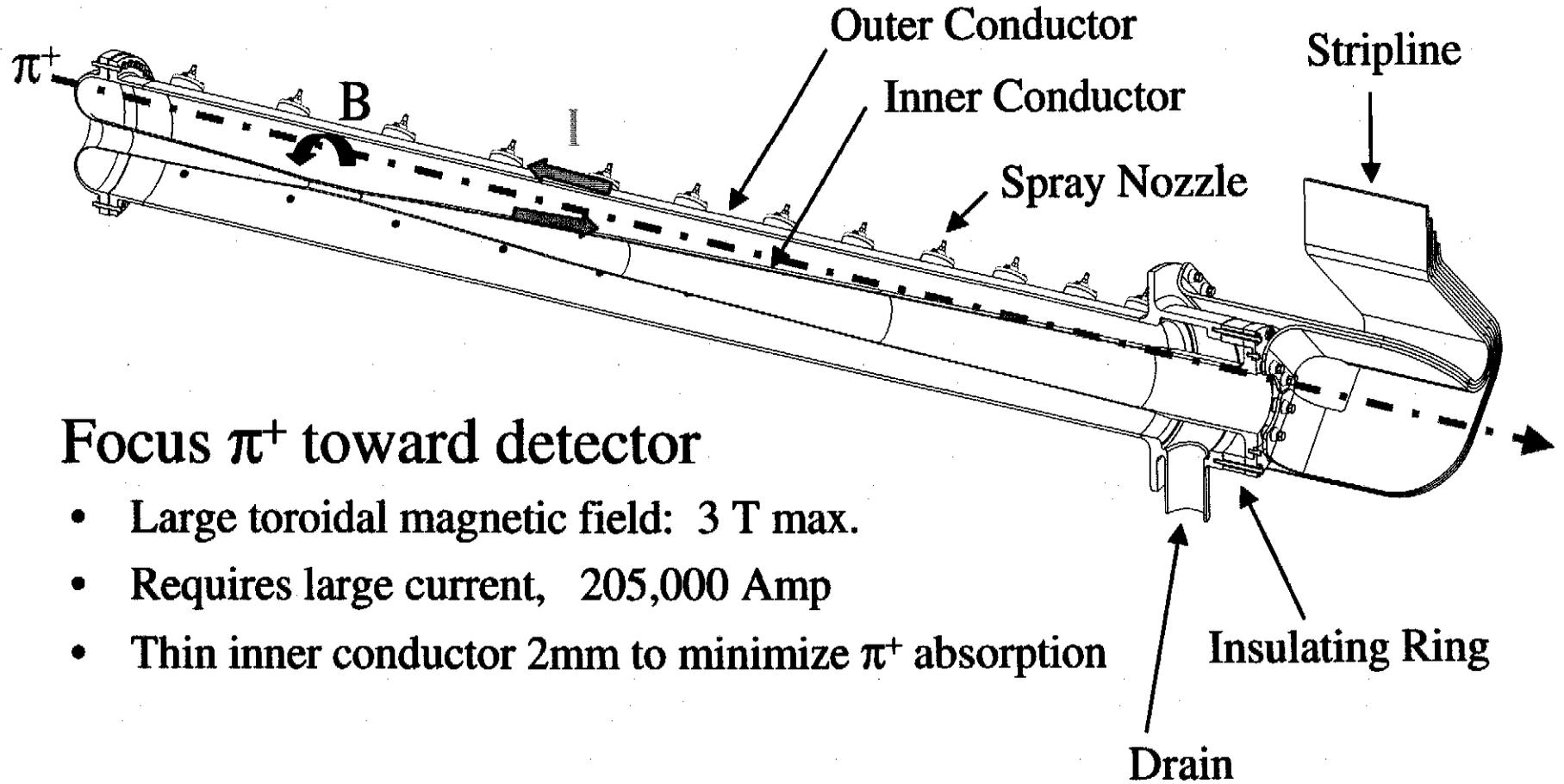
but

Small p-beam spot size \rightarrow high stress



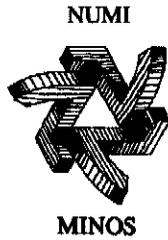


Magnetic Horn (1 of 2)



Focus π^+ toward detector

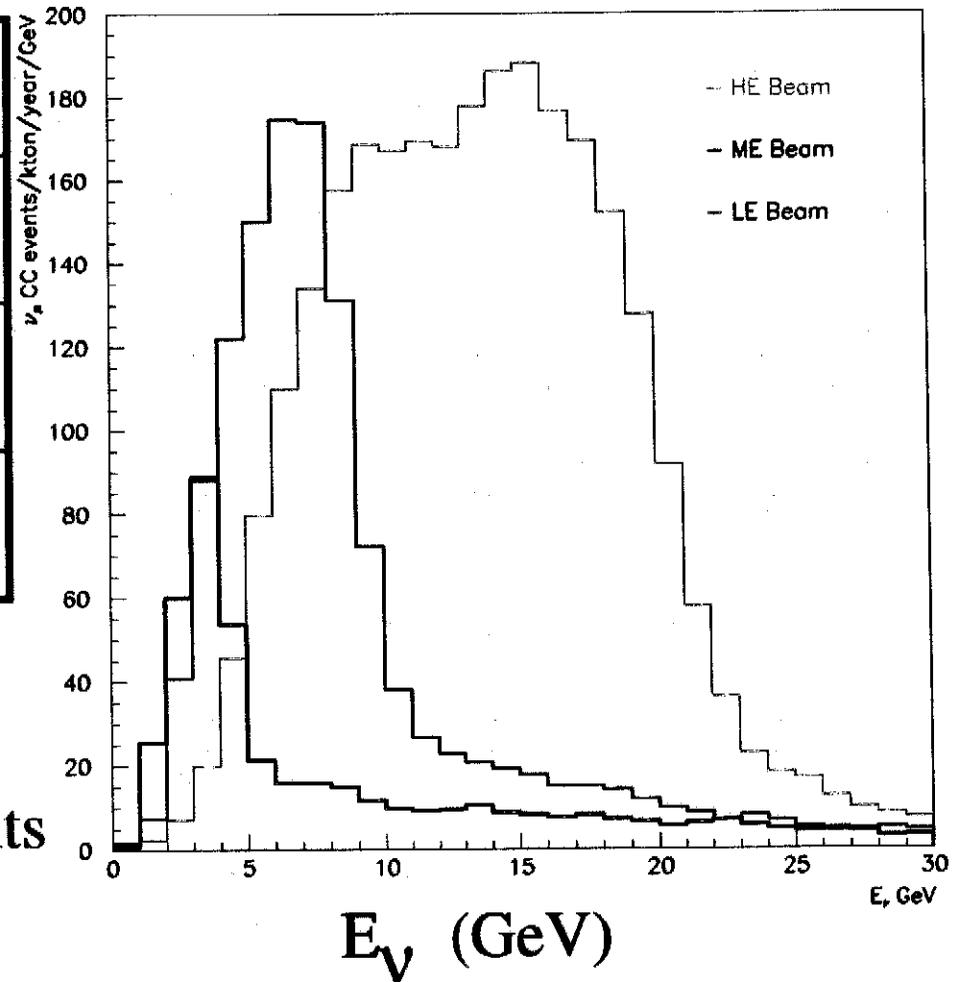
- Large toroidal magnetic field: 3 T max.
- Requires large current, 205,000 Amp
- Thin inner conductor 2mm to minimize π^+ absorption



We change Neutrino Beam Energy by moving/changing target

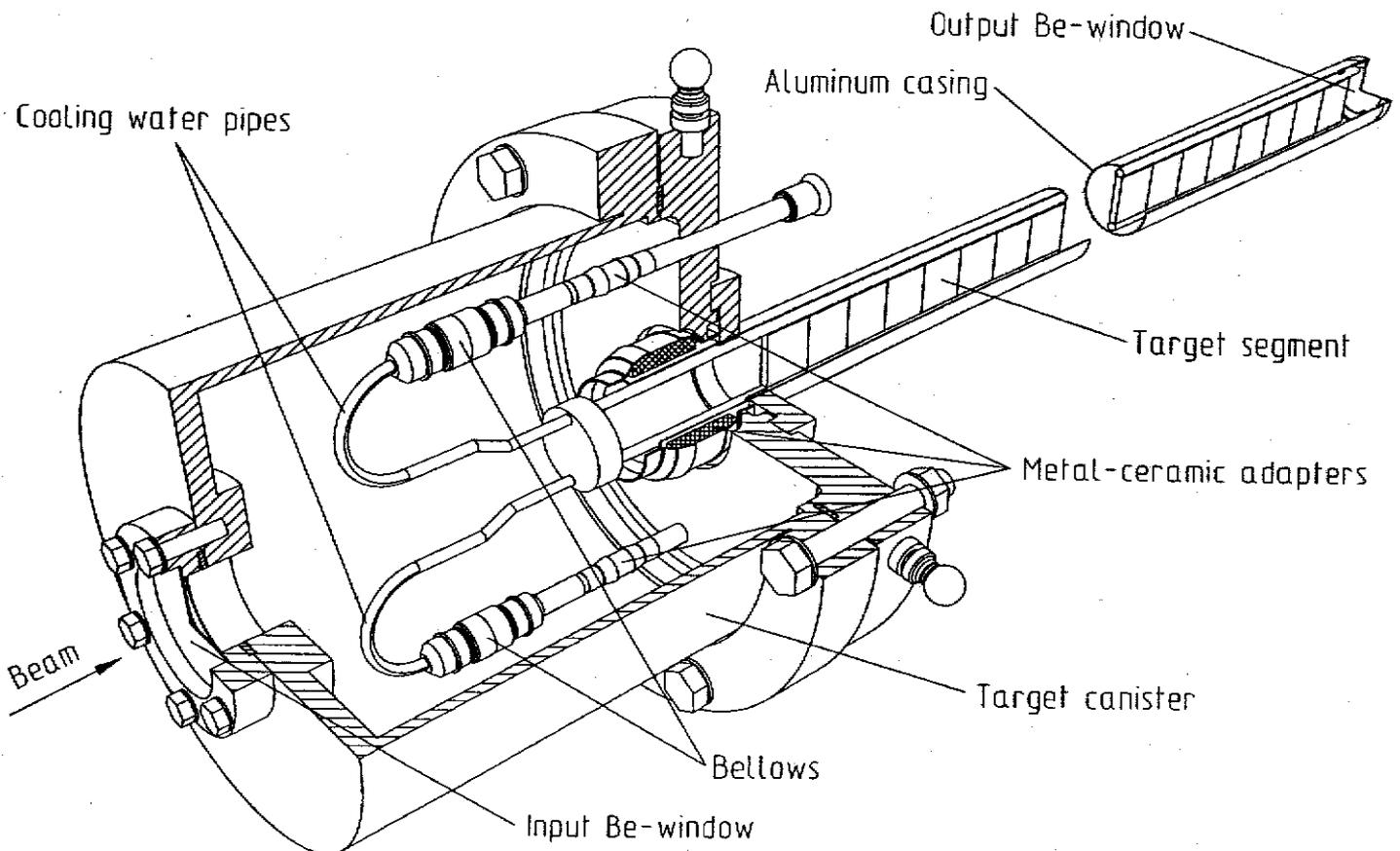
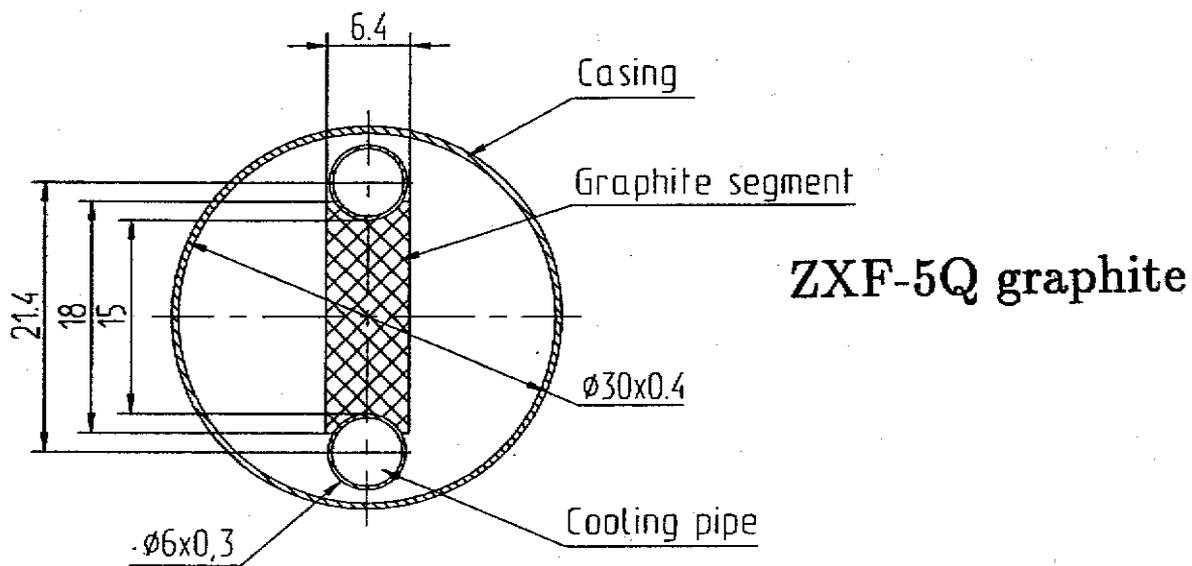
	Low	Med.	High
Target Length	94 cm	120 cm	160 cm
Target-horn Spacing	-60 cm <i>in horn</i>	20 cm	240 cm
Target Density	1.74 g/cm ³	1.54 g/cm ³	1.16 g/cm ³

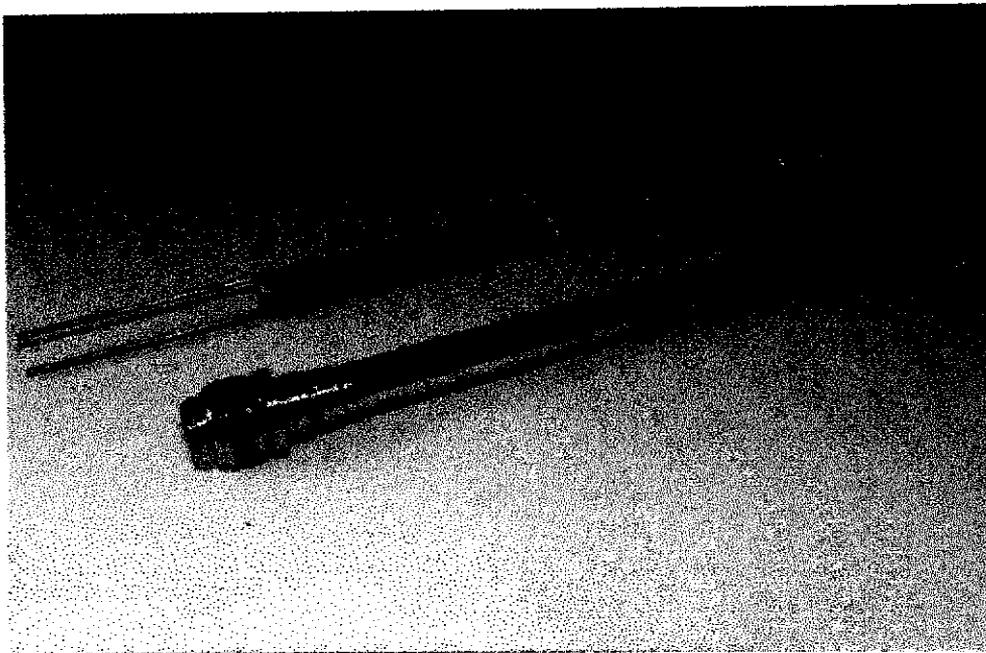
Target density adjusted by
leaving gaps between segments



NuMI Low Energy Target

3 GeV ν from 0.4 MW proton beam





Energy deposition (kW) in different elements of the LE target:

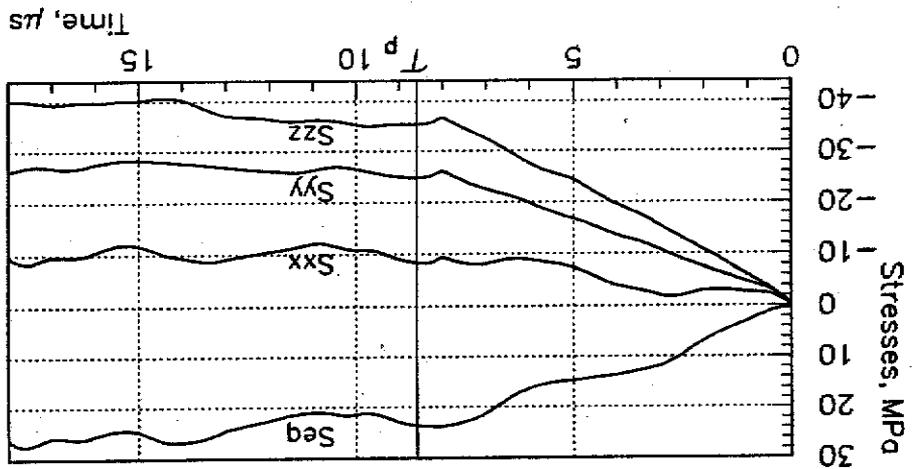
Graphite segments	2.959
Cooling pipes and water	0.415
Aluminum casing	0.148
Total	3.523

Main parameters of the LE target cooling system:

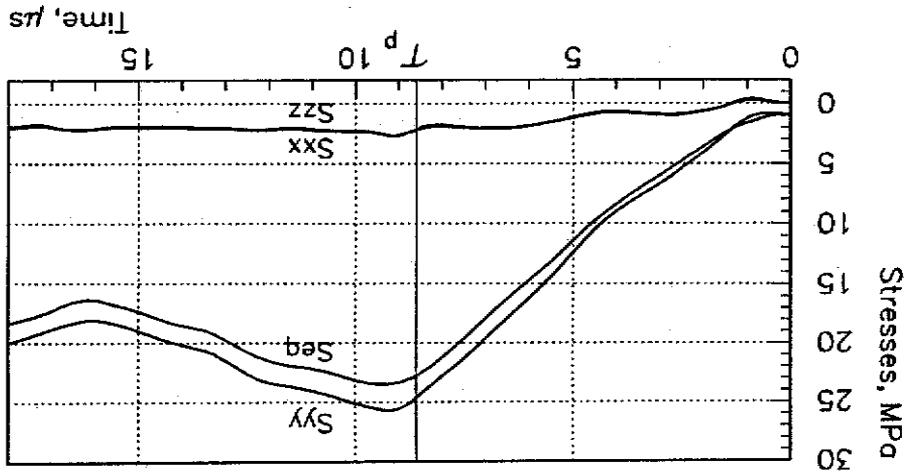
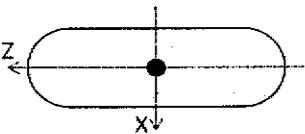
Velocity of a cooling water, m/s	2	3	4
Heat transfer coefficient, kW/m ² /K	10	14	18
Pressure drop, atm	0.32	0.68	1.2
Water flow rate, l/min	2.7	4.1	5.5
Water temperature rise, °C	18	12	8.8

For the target segments with the highest energy deposition density ($\sim 0.095 \text{ GeV/cm}^3/\text{p}$):

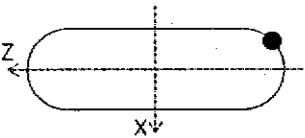
Temperature before beam spill	58.2°C
Temperature rise	272°C
Temperature after beam spill	330°C



$$(S^{eq})_{max} = 27.4 \text{ MPa}$$



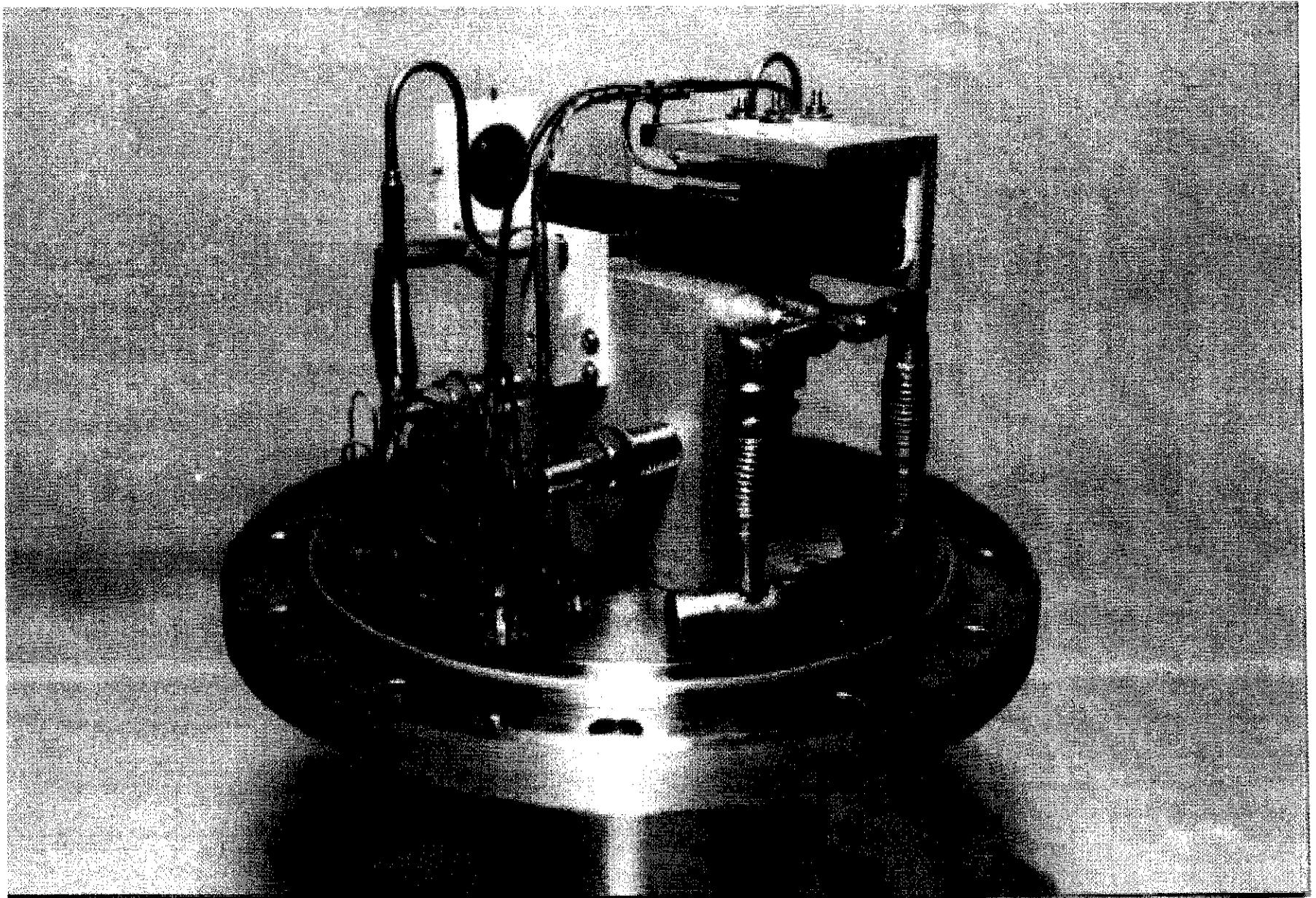
$$(S^{eq})_{max} = 23.5 \text{ MPa}$$



ZXF-5Q (1.81 g/cm³): Compressive Strength 210 MPa
Tensile Strength 95 MPa

The high cycle fatigue endurance limit of graphite is 0.5-0.6
The safety factor is $\frac{(0.5-0.6) \times 95}{23.5} \sim 2.2$

NuMI Prototype Target for Beam Test



Scaling from the full-size ME target to prototype:

ME Target	Full-size	Prototype
Beam energy, GeV	120	120
Number of protons per spill	$4 \cdot 10^{13}$	$5 \cdot 10^{12}$
Beam size $\sigma_x \times \sigma_y$, mm ²	0.7×1.4	0.3×0.3
Segment width, mm	3.2	1.78
Segment length, mm	20	8.0
Maximum energy deposition density, kJ/cm ³	0.70	0.86
Temperature at the beam axis, °C:		
T_{max}	508	467
ΔT	280	394
T_{min}	228	73
S_{eq} at the center of segment, MPa	25	27



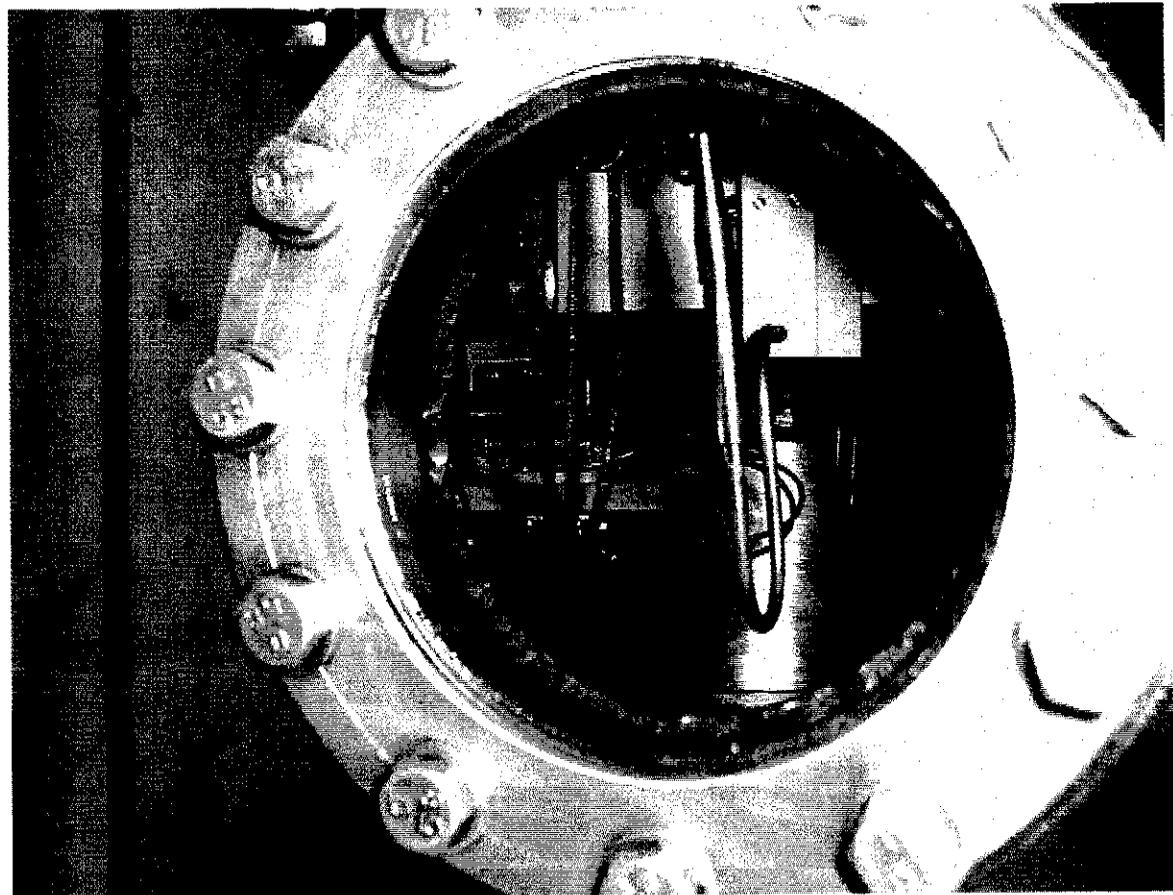
Prototype Target Test

Target teeth show no damage after
 7×10^{17} protons

3×10^5 pulses
 2×10^{18} protons/mm²
(about 1 NuMI
design week)

Max. stress pulses:
 1×10^{13} /pulse
0.2 mm RMS spot

(NuMI Design:
 4×10^{13} /pulse
0.9 mm RMS spot)





Target Budal Monitor *in test beam*

- 1) Electrically insulate target
- 2) Scan beam across target
- 3) Delta rays knocked out induce target voltage
- 4) Electronic readout of target = Budal Monitor

Highest signal is at edges of target

Better signal-to-noise for target-in-vacuum
than target-in-He

In Helium, insulator coated (silicon nitride) graphite
gets less background than bare graphite

Can locate target to ~ 0.1 mm

